B

Appendix B - Engineering and Summary of Plan Concepts and Potential Elements

Appendix B – Engineering Concepts and Potential Elements

Table B-1 shows the range of concepts that were identified for the rehabilitation study. Some of the concepts were quickly rejected, others were subjected to more analysis and costs were developed. All of the jet flow designs were eventually rejected for clamshell designs because jet flow valves operating while submerged exhibit vibration problems. Table B-1 is arranged by category of concept and does not reflect the linear path of development and analysis of concepts.

Table B-1. Outlet Gate Configurations and Construction Elements Identified

Concept or Potential Element	Discussion
Current Valve Design	
Retain current design	This is part of No Action Alternative.
Retain existing Ensign valves, install new liners, and renovate 2 valves per year	Rejected. Cannot fully meet water release objective.
Modify upper row of Ensign valves	Rejected. Cannot fully meet water release objective.
Jet Flow Valve Designs (Note jet flow valves were rejected in favor of a clamshell design)	
Install seven 48-inch jet flow gates (replace seven Ensign valves of the lower tier). Includes downstream valve house with elevator	Rejected due to high cost and would require continued use of upper row of Ensign valves.
Install three 68-inch jet flow on the three power outlets (replace Ensign valves 1, 2, and 3) and include an upstream moveable wheel mounted guard gate	Rejected. Space too small for three 68-inch jet flow gates.
Install three 96-inch jet flow gates with 102-inch ring follower gates on power outlets 1 and 3 and outlet 4 (replace Ensign valves #1, #3, and #4). Ream conduits from 72-inch to 120-inch diameter. Install steel liners. Includes downstream gate house and stop logs	Rejected due to costs.
Install two 96-inch jet flow gates with 102-inch ring follower gates on power outlets 1 and 3 after reaming conduits from 72-inch to 120-inch size	Rejected in favor of a higher coefficient discharge, lower cost, and reduced vibration with submerged clamshell gates.
Clamshell Gate Designs	
Install seven clamshell gates (48-inch diameter) (replace seven Ensign valves in the lower row). No gate house	Rejected. Would require retention of the upper Ensign valves to meet flow objective.
Install seven 48-inch and three 66-inch clamshell gates to replace lower row of Ensign valves.	Selected and included in the action alternatives.
Install three 68-inch clamshell gates on power outlets (replace Ensign valves 1, 2, and 3) and retain upper Ensign valves	Rejected. Upper row of Ensign valves needed to meet flow objectives. (68-inch clamshell gates have not been tested.)
Construct new outlet tunnel, control valves, and tailrace as part of future powerplant construction.	Proposed powerplant has been shelved due to lack of economic justification and high pool maintained by Lucky Peak Dam.

Table B-1. Outlet Gate Configurations and Construction Elements Identified	
Concept or Potential Element	**Discussion**
Install three 96-inch clamshell gates on the three power outlets, bore conduit from 72-inch to 102-inch diameter and install steel liner. Includes movable wheel mounted guard gate on upstream; no gate house required	Rejected due to costs and flexibility.
Install 48-inch clamshell gates (replaces the l0 lower Ensign valves). No upstream guard gate	Rejected. Would require retention of some of the upper Ensign valves to meet flow requirements.
Use fixed cone valves	Rejected. Not commonly used for submerged applications.
Spillway Modification	
Lower spillway crest by 9 feet for two of the 62-foot bays and install Obenmeyer Gates.	Rejected. Alternate to retention of upper Ensign valves. Least cost alternative to increase spillway capacity at lower reservoir levels.
Water Supply Below Lower Row of Ensign Valves	
Abandon the 3,000 acre-feet of contracted storage space between the sluice gates and the lower row of Ensign valves	Rejected. Siltation has probably reduced this space and water could be supplied from Anderson Ranch Reservoir. Allowing sluice gates to silt in is considered a better option.
Provide alternative water supply from Lucky Peak Lake by raising the dam	Not cost effective and facility is not under the jurisdiction of Reclamation.
Construction Period and Reservoir Drawdown	
Two-year construction. First year draw down Lucky Peak to elevation 3010 (October through February). Second year draw down Arrowrock Reservoir to elevation 3026. Do not use sluice gates.	Unable to complete construction in 2.
Two-year construction. First year draw down Lucky Peak to elevation 3010 (September through February) Second year drawdown Arrowrock Reservoir to elevation 3026 (September through February). Use sluice gates.	Not feasible. Construction period is insufficient.
Three-year construction. First and second years draw down Lucky Peak to elevation 3000 feet (September through February) and maintain Arrowrock Reservoir above 3110 feet. Third year draw down Arrowrock Reservoir to elevation 3027 (September 15 through February) and draw down Lucky Peak to elevation 3000 (September 15 through October) and then to elevation 2964 (November through February). Use sluice gates.	Included in Alternative A.
Three-year construction. First and second years draw down Lucky Peak to elevation 3000 feet (September 15 through February) and maintain Arrowrock Reservoir above 3110 feet. Third year draw down Arrowrock Reservoir to elevation 3007 feet and draw down Lucky Peak to elevation 2962 feet (September through October). Use sluice gates.	Included in Alternative B.

Table B-1. Outlet Gate Configurations and Construction Elements Identified	
Concept or Potential Element	**Discussion**
Four-year construction period using a cofferdam on upstream side of Arrowrock Dam. First and second years draw Lucky Peak to elevation 3010 feet (September through February). Third and fourth years draw Arrowrock to elevation 3078 feet (September through February). Sluice gates not used.	Rejected due to safety concerns, costs, and limited area within the coffer dam for removal of Ensign valves. Concrete of upstream surface of the dam has deteriorated to the point that failure of a seal would be highly probable.
Four-year construction period using divers. Otherwise the same as above.	Rejected. Does not improve reservoir levels but costs more than Alternative B.
Unknown construction period using a pressure vessel to eliminate need for drawdown of Arrowrock Dam.	Not feasible due to extraordinary costs.
Clamshell Gates	
Mount clamshell gates on downstream face of dam (minimize excavation)	Included in both action alternatives.
Set clamshell gates with barge and crane	Included in Alternative A & B as a contractor option.
Set clamshell gates with helicopter	Rejected. Would have minimal impact.
Set clamshell gates with overhead cable system	Rejected. No apparent advantage.
Strengthen existing dam and use a large crane	Included in both action alternatives.
Construct steel bridge at elevation 3054 on face of dam	Rejected. No apparent advantage.
Other Possible Installations	
Install gates in middle of dam	Rejected. No apparent advantage.
Install clamshell gates on upper row of outlets	Rejected. Would reduce discharge below design requirements.
Selected level outlet works for upper row of outlets	Rejected. No apparent advantage.
Pipe Liners	
Pull pipe liners	Impractical.
Push pipe liners	Included in action alternatives.
Set from a barge	No decision. Would have minor impact.
Set with cranes/barges	No decision. Would have minor impacts.
Install penstock in pieces	Included in action alternatives.
Install pipe in sections	Included in action alternatives.
Use HDPE pipe liners	Rejected. No apparent advantage, may have disadvantages.
Use a flexible Liner	Rejected. No apparent advantage ,may have disadvantages.

Table B-1. Outlet Gate Configurations and Construction Elements Identified	
Concept or Potential Element	**Discussion**
Remove Ensign Valves and Set Bellmouths	
Lower reservoir	Included in preferred alternative.
Use divers	Rejected due to cost and operational constraints. No advantage over using a caisson.
Use cofferdam	Rejected due to safety and cost considerations.
Use pressure vessel	Considered impractical due to high costs.
Use bulkheads to set bell mouths	Considered impractical (trashrack frame lacks required strength to support bulkheads).
Disposal of Ensign Valves	
Remove and dispose of Ensign valves	Included in action alternatives.
Cut valves and drop into reservoir	Could require permit from Corps.

Engineering Concepts for Alternatives

The primary operational objective identified in all replacement studies was the flow requirement or minimum outlet discharge capability at various reservoir elevations. Table B-2 summarizes the minimum discharge capacity required. A second objective was to reduce maintenance, especially the need for reservoir drawdowns to maintain the lower outlet facilities.

Table B-2. Operational Objectives

Water Surface Elevation (Feet)		Minimum Discharge Capacity (Cubic Feet per Second)
Arrowrock Reservoir	Lucky Peak Lake	
3100	3055	5,000
3115	3018	10,000
3210	3018	11,000

The early concepts focused on fewer but larger capacity outlet works and relocating the outlet works to the downstream side of the dam to alleviate the need to lower Arrowrock Reservoir elevations for maintenance. However, none of the earlier concepts appeared viable. Most early concepts included boring holes as large as 10 feet in diameter in the dam or required the retention of the upper valves to meet operational criteria. The early concepts not only were costly, but also raised questions as to the structural stability of the dam with extensive excavation. An additional problem of early designs was that many of the valves evaluated could not discharge in a submerged condition. Discharge capability in a submerged condition is a primary requirement since the tailwater of Lucky Peak Lake, during part of the year, inundates the lower row of discharge conduits now controlled by Ensign valves.

In 1987, the possibility of using clam shell gates, an emerging technology, was proposed as an alternative to other types of valves. They appear to meet the needs at Arrowrock Dam. Clamshell gates have high discharge capacities which would meet Arrowrock operational objectives without enlargement of the existing outlet conduits. In addition, they are able to discharge into the air or underwater and are designed to be located on the downstream end of the conduit, eliminating most cavitation concerns and the need to lower the reservoir for gate maintenance.

Several matters under consideration in the late 1980's and early 1990's led to a delay in further investigation of clam shell gates as a solution. Over a period of several years, the Boise Project Board of Control investigated the potential for construction of a powerplant at Arrowrock. A powerplant, had it been developed, would have solved part of the outlet facilities concerns.

In 1987, Reclamation lowered the Arrowrock Reservoir pool to investigate the condition of the sluice gates and found major maintenance problems involving cavitation damage downstream from the gates. Following this finding, the Snake River Area Office, over a period of years, programed funding to repair the sluice outlets as an action separate from resolving the Ensign

valve problem. Funding was deferred pending a decision on a course of action for rehabilitating the outlet works.

Since 1988, high water elevations of Arrowrock Reservoir have not provided an opportunity for further inspection of the lower valves. This precipitated a reinvestigation of the valve maintenance issue in the late 1990's. Findings of this investigation indicated that the various maintenance issues at Arrowrock Dam needed to be addressed on a holistic basis.

During the scoping process, Reclamation presented the conceptual design and outlined a construction scenario which included drawing down Arrowrock Reservoir in the last year of construction to access and remove the Ensign valves. A primary concern expressed during scoping was the potential environmental effects of Arrowrock Reservoir drawdown needed to accomplish the work. Based on that input, Reclamation investigated methods of construction that would not require reservoir drawdown below normal fluctuation levels or would minimize drawdown.

Reclamation formed a value engineering team in 1999 to evaluate costs, time frames, and various factors for achieving construction without drawdown of the reservoir. The value study team compared the construction scenario presented in the scoping process with three construction options that would require less or no drawdown through use of (1) a steel cofferdam, (2) an upstream pressure vessel, or (3) construction by underwater divers (Reclamation, 1999b).

The upstream pressure vessel was eliminated because costs would be extravagant, in excess of three times the cost of the original construction concept. The cofferdam option and the dive option seemed feasible on first evaluation so were carried forwarded for further evaluation of constructability. In a draft constructability report (Reclamation, 1999c), the cofferdam was eliminated from further consideration based on insufficient space to install a cofferdam within the trashrack compartment and still provide space to remove the valves. A means of safely enlarging the size of the cofferdam to accommodate removal of the valves was not found. The cofferdam option also suffers from a serious safety concern. The ability to seal the cofferdam to the face of the dam appears limited with the potential for failure and a high level of risk to workers within the cofferdam during construction.

Underwater construction on the upstream face of the dam was investigated and found to be technically feasible, but costly. Three scenarios that varied from accomplishing all construction to varying amounts of work underwater were examined. The cost estimates for the three options varied from $2.5 million to $7 million. Underwater construction was eliminated on the basis of cost (Reclamation, 1999).

No Action Alternative

Facilities

Lower Ensign Valves

Ensign valves 1 through 10 were inspected in 1987 and minor repairs were made in 1988. Valve 1, taken out of service in 1940 due to concrete damage, continues to be out of service. Valves 2 and 3 were taken out of service when the 1987 inspection found extensive cavitation damage to the concrete conduit downstream of the valves and the inspection team recommended that repairs be made before again operating valves 2 and 3. Current policy on operation of valves 2 and 3 is that they are locked out of service except under emergency conditions. Under the No Action Alternative, valves 1, 2 and 3 would require considerable repair to return to service, and the remaining valves would require continued maintenance as detailed below.

To effectively maintain the Ensign valves for the long term, three or four valves would be overhauled every 6 years to ensure that every valve would be overhauled at least once every 18 years. Reservoir drawdown would be required for each overhaul period with repairs requiring at least 1 month per valve.

Sluice Gates

Sluice gates at Arrowrock dam were last operated in 1988 to draw down the reservoir to perform maintenance work on the lower level Ensign valves. At that time, inspection of the downstream surfaces of the sluice gates revealed only minor cavitation and erosion damage to gates 1, 2, and 4. In contrast, gates 3 and 5 showed considerable erosion and cavitation damage downstream of each gate. The inspection report dated Sept 23, 1988, found sluice gates 1, 2, and 4 to be operational but recommended the operation of gates 3 and 5 be avoided.

Due to the extensive cavitation damage downstream of gates 3 and 5, these gates would be repaired first. After the intensive repair and replacement program, each sluice gate would be re-inspected, evaluated, and repaired as necessary at least once every 12 years. Inspections and repair of the sluice gates would be coordinated with the inspection of the lower Ensign valves. The repair period for sluice gates is estimated at a minimum of one month per gate.

Reservoir Drawdowns

Maintenance Season 1 drawdown of Arrowrock Reservoir would be primarily for the purpose of inspection and data collection for upcoming construction contracts; some minor cavitation damage would likely be repaired during the first year. Arrowrock Reservoir elevation would be 3007 feet and Lucky Peak Lake elevation would be at 2962 feet or lower (within the normal winter range of 2943-2972 feet) from November 1 to January 1.

Maintenance Season 3 drawdown of Arrowrock Reservoir would be for major repair of sluice gates 3 and 5; major overhaul of Ensign valves 2-4; and inspection and minor repair of Ensign valves 5-10. Arrowrock Reservoir elevation would be 2975 feet, and Lucky Peak Lake elevation

would be at 2962 feet or lower (within the normal winter range of 2943-2972 feet) from October 1 to March 1.

Maintenance Season 9 drawdown of Arrowrock Reservoir would be for major overhaul of Ensign valves 5-8 and inspection and minor repair of Ensign valves 2, 3, 4, 9, and 10. Arrowrock Reservoir elevation would be 3007 feet, and Lucky Peak Lake elevation would be at 2962 feet or lower (within the normal winter range of 2943-2972 feet) from October 1 to March 1. Although the sluice gates would not be worked on in this year, a Lucky Peak Lake level of 2962 or lower would be necessary to pass possible flood inflow through Arrowrock Dam sluice gates.

Maintenance Season 15 drawdown of Arrowrock Reservoir would be for major repair of sluice gates 1, 2, and 4; major overhaul of Ensign valves 1, 9, and 10; and inspection and minor repair of Ensign valves 2-8. Arrowrock Reservoir elevation would be 2975 feet and Lucky Peak elevation would be at 2962 feet or lower (within the normal winter range of 2943-2972 feet) from October 1 to March 1.

Maintenance Season 21, and every 6 years thereafter, Arrowrock Reservoir would be drawn down for the purpose of inspection and minor cavitation repair of the lower Ensign valves and disassembly, inspection, cleaning, and repair of three or four Ensign valves. The schedule would ensure that (1) each Ensign valve is overhauled at least once every 18 years and (2) that sluice gates would be inspected and repaired as necessary once every 12 years. Arrowrock Reservoir would be drawn down to 3007 feet in years when just the Ensign valves were to be worked on and to 2975 feet in those years when the sluice gates would be inspected and repaired. Lucky Peak Lake would be drawn down to elevation 2962 feet or lower (within the normal winter range of 2943-2972 feet) from October 1 to March 1 in each maintenance year.

Alternative A

Facilities

The seven existing 52-inch diameter conduits would be lined with 48-inch inside diameter steel pipe, and the three existing 72-inch diameter power conduits would be lined with 66-inch inside diameter steel pipe. These liners would be grouted in place. Bellmouths would be mounted on the upstream face of the dam in place of the Ensign valves and welded to the liners.

Seven 48-inch and three 66-inch clamshell gates would be attached at the downstream end of the new steel conduit liners and mounted on the downstream face of the dam. These gates would be hydraulically operated. Construction on the downstream side of the dam would also include a concrete control house and access to the new clamshell gates on the left side of the dam.

The two existing trashracks on the upstream side of the dam would be modified to accept a bulkhead gate sized to fit over both the 48- and 66-inch bellmouth inlets. Bulkhead gate guides would be installed on the face of the dam to allow insertion of the bulkhead gate at any reservoir elevation. A bubbler system would be installed on the dam face to keep the bulkhead gate guides free of ice. When lowered into place the bulkhead gate would seal the conduit portal on the

upstream side to provide dry conditions for future outlet maintenance without requiring drawdown of Arrowrock Reservoir.

Construction Schedule and Reservoir Drawdown

Construction Season 1 activities will be limited to the downstream face of Arrowrock Dam. Activities will include mobilization for construction, excavation of concrete for clamshell gates, placement of concrete, and construction of the control house. Arrowrock Reservoir elevation will be maintained at no lower that 3110 feet and Lucky Peak Lake elevation will be maintained no higher than 3000 feet from September 15 to March 1.

Construction Season 2 activities will be limited to the downstream face of Arrowrock Dam. Activities will include installation of steel liners; clamshell gates; and mechanical, electrical, and hydraulic controls; placement of additional concrete; construction of access routes within the dam to maintain valves; and preparation for upstream work the following year. Arrowrock Reservoir elevation will be maintained at no lower that 3110 feet and Lucky Peak Lake elevation will be maintained at no higher than 3000 feet from September 15 to March 1.

Construction Season 3 activities will be on the upstream face of Arrowrock Dam. The Ensign Valves would be removed in sets of three, four, and three starting with Ensign Valves 1-3. Arrowrock Reservoir would be drawn down to elevation 3027 feet and briefly below that elevation to install stoplogs in the trashrack structures of the first three conduits to maintain dry working conditions. After the Ensign valves in the first set are removed and the bell mouths are installed, the reservoir could be briefly drawn down below elevation 3027 feet, and the stoplogs maintaining dry conditions would be moved to the next set and then to the last set. As a result there would be flow to the conduits of each completed set and the outlets would become functional with outlet control switched to the downstream clamshell gates. Since only three or four conduits would be inoperable at any time, there would always be six or seven conduits to pass inflow throughout the construction period. In response to water quality concerns, if Arrowrock Reservoir inflow is in excess of available Ensign valve capacity, the work site would be allowed to flood for up to five days cumulatively before sluice gates would be opened to lower the water level.

Activities in Construction Season 3 will include removal of Ensign valves, installation of bell mouth liners, installation of bulkhead guides, and completion of the control system. It is anticipated that placement and removal of stoplogs will be done under water. If for some unseen reason, dry placement of the bulkheads is required, Arrowrock Reservoir would be temporarily drafted to provide dry conditions. Lucky Peak Lake would be at or below elevation 3000 feet by September 15 and maintained at or below 2962 feet from November 1 to March 1. These elevations are within the normal operating range of Lucky Peak Lake for irrigation water supply, flood control, and other project purposes.

Alternative B

Construction Schedule and Reservoir Drawdown

Construction on the downstream side of Arrowrock Dam during years 1 and 2 would be identical with those for Alternative A, taking place between September 15 and March 1.

Construction Season 3 activities will be on the upstream face of Arrowrock Dam as in Alternative A, but stoplogs will not be installed in the trashrack structures. Arrowrock Reservoir would be drawn down to elevation 3007 feet by September 1 and would be maintained at that elevation until November 7, which provides 9 weeks for the contractor to work in the dry. Lucky Peak Lake would be maintained at elevation 2962 feet or lower during this period. The use of sluice gates to pass inflows is necessary throughout Construction Season 3.